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FORMULATION OF CONSUMABLES MANAGEMENT MODELS

AUGUST 1978

CONTRACT NO. NAS9-14264

EXECUTIVE SUMMARY

Prepared by

J. G. Torian

Operational Systems Section

TRW

DEFENSE AND SPACE SYSTEMS GROUP

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TABLES

The final report for Part IV of this contract is presented in an Executive Summary and two technical volumes. The technical volumes are: Volume I-Mission Planning Processor Development and Volume II-Mission Planning Processor User Guide.

Several formal reports were issued during the period of performance of Part IV and are so noted in the References of the Executive Summary and Volume I.

This particular report presents information on development of the Consumables Mission Planning Processor.

1.0 INTRODUCTION

Future manned space programs that will have increased launch frequencies and reusable systems require an implementation of new consumables and systems management techniques that will relieve both the operations support personnel and flight crew activities. These techniques must be developed for the optimum combination of an onboard and ground support consumables management system consistent with the goals of the program. Effective operational performance of the consumables management techniques of a total system requires that a very explicit definition of the time, place, and method of performance of each function be determined by trade studies to ascertain that the operational methods do, indeed, meet these goals. This requires that the complete consumables management cycle be considered by including the mission planning and scheduling functions, prelaunch activities, onboard mission functions, ground mission support functions, and postmission activities.

Formulation of models required for the mission planning and scheduling function and establishment of the relation of those models to prelaunch, onboard, ground support, and postmission functions for the development phase of advanced spacecraft was conducted under Contract NAS9-14264.

Analytical models and techniques were developed which consist of a Mission Planning Processor (MPP) with appropriate consumables data base, methods of recognizing potential constraint violations in both the planning and flight operations functions, and Flight Data Files for storage/retrieval of information over extended periods interfacing with Flight Operations Processors for monitoring of the actual flights. Consumables subsystems considered in the MPP were electrical power, environmental control and life support, propulsion, hydraulics and auxiliary power.

Development of Space Transportation System (STS) interactive computer program MPP working model was conducted under Part IV of this Research and Technology Objectives and Plan (RTOP) and is based on studies conducted during the preceding Parts I, II and III. The period of performance for Part IV was 1 November 1976 through 31 August 1978.

The final report for Part IV of this contract is presented in an Executive Summary and two technical volumes. The technical volumes are: Volume I-Mission Planning Processor Development, and Volume II-Mission Planning Processor User Guide.

Several formal reports were issued during the period of performance of Part IV and are so noted in the References of the Executive Summary and Volume I.

This particular report presents an overview of the effort conducted under Part IV of the RTOP.

2.0 PROGRAM DEVELOPMENT AND SUPPORTING TASKS

2.1 STS MPP WORKING MODEL

Analytical models and techniques were developed which consist of an MPP with appropriate consumables data base. The MPP is used to calculate consumables requirements and to provide a method for recognizing potential constraint violations in both the planning and flight operations functions. In addition, the MPP generates a Flight Data File for storage/retrieval of information over an extended period which interfaces with a Flight Operations Processor for monitoring of the actual flights.

A working computer model of the MPP for the STS was developed under Part IV of the RTOP. The program is structured as defined by the detailed requirements of Reference 1. The program is in operation on the Univac 1110-Exec 8 System accessible through the Mission Planning Laboratory terminals in Building 30 at the Johnson Space Center (JSC). The program may be operated either from tape or secured files. Application of the program is explained in Volume II of these reports.

Features of the MPP are summarized in Table I. The program is designed to afford routine processing of the consumables aspect of mission planning and flight operations by personnel not specifically skilled in consumables technology. This design goal is accomplished by use of an on-line/demand mode computer terminal Cathode Ray Tube (CRT) display. The process is such that the user merely adds specific mission/flight functions to a skeleton flight and/or alters the skeleton. The skeleton flight includes operational aspects from prelaunch through Ground Support Equipment (GSE) connect after landing and rollout. These operations are required to place the STS in a parking orbit, maintain the spacecraft and crew for the stated on-orbit period and return. The system has an update/edit capability such that the fidelity of the resulting consumables data can be increased as the user knowledge of that particular flight increases or replanning is necessary over a span time of approximately ten years from the long-range planning stage through flight operations.

Table I. Mission Planning Processor Features

- Developed for routine processing and screening of high frequency repetitive flights by relatively unskilled personnel.
- Simplified user interface:
  - Interactive demand mode computer program
  - User need not be a consumables analyst
  - User prompting and error guards
  - Constructs timeline from menu of phases and activities.
- Records and notifies user of scheduling conflicts and potential constraint violations.
- File/retrieval and update/edit system developed for extended flight planning/flight operations period with flight being designed and processed in parallel.
- Structured such that it may be integrated into overall mission planning system.

Demonstration of the file/retrieval and update/edit capability of the MPP was conducted via preparation of data files for operational flights beyond Orbital Flight Test (OFT)-6. The efforts demonstrate the preparation of early-stage flight planning data files based on the best information available on each individual flight and the techniques for updating the data as the flight planning process progresses. The MPP was exercised for 27 flights categorized as Single Payload Deployable, Multi-Payload Deployable, Department of Defense (DOD), Spacelab, and Other Flights. The File 1 data (input) has been placed in secured files for retrieval. The files can be retrieved for update/edit and/or generation of consumables data on the flights as currently planned. The preparation of these files provides JSC with a system for training personnel as well as initializes the operational era consumables management system. A significant feature of the file/retrieval system is that it virtually eliminates the maintaining and updating of written reports on the planning status of the flights, since the latest information can be retrieved as needed.

The program as structured consists basically of control and support routines, computational routines, and a consumables data base. In execution, the user, via the control and support routines, is setting up indicators as to the start and stop time of various activities. These indicators direct the computational routines to calculate the effect of the activity on the consumables. The computational routines extract data on each activity from the consumables data base. This structuring provides the potential to integrate the consumables aspect of mission planning into an overall mission planning processor. This could be accomplished by using the consumables computational routines and data base with the indicators being supplied as a sub-set of the indicators required for the overall mission planning process.

2.2 SUPPORTING TASKS

Development of the Mission Planning Processor Computer Program under Part IV of this RTOP was supported by several parallel tasks. These tasks either directly supported the program development, or provided information

for future application and/or modification to the program in relation to the flight planning and flight operations of the STS and advanced spacecraft. These studies are in addition to similar, but more generic, studies conducted under previous parts of the RTOP. This report presents an overview of the individual tasks. The reader is referred to Volume I of these reports and/or the References for greater detail.

STS MPP Validation Study

A study was conducted to determine accuracy of the MPP as a consumables analysis tool in relation to detailed consumables studies conducted by the Mission Planning and Analysis Division (MPAD) at JSC. Consumables requirements for the OFT flights were developed on the MPP and compared with similar data from the MPAD/JSC studies (References 2 and 3). The standard deviation (σ) based on the percent of total consumables required as calculated in the MPP and those found in the MPAD/JSC studies is shown in Table II.

Table II. Validation Study Results, Standard Deviation

CONSUMABLE	σ
OMS PROP	2.4
CRYO (H_2/O_2)	3.2
ECLSS N_2	1.0

Data Base Update for STS MPP

The Consumables Data Base associated with the performance of the mission activities and required as input to the STS MPP for the consumables calculations has been prepared under Part III of this RTOP. Under Part IV the information was updated to reflect current data for incorporation in the computer program. The updated information is given in Reference 4.

Payload Interface Requirements Task

A study defining the payload interface to the MPP was conducted. The study is documented in Reference 5 which:

1. Defines the impact of payload functions on Orbiter operations.
2. Provides a guide to assessing this impact via reference to a typical payload data source and the related input to the MPP.
3. Identifies modifications to the MPP which will improve the interface of the payload data source and the Processor.
4. Identifies the data and format for payload data sources which would improve the interface of that source and the MPP.

Crew Simulator Requirements Task

A study was conducted to define the crew training simulations requirements relating to consumables management for advanced spacecraft systems. The Space Shuttle requirements were examined in detail as a specific example of such an advanced system. The study recommends development of a "consumables reset point generator" based on the MPP program for inclusion in the simulator software package.

The recommendations were documented (Reference 6) and presented in a briefing to representatives of the National Aeronautics and Space Administration (NASA) Flight Simulations Division at JSC.

Flight Data File 3 Development

The algorithms required for the generation of the Flight Data File 3 by the MPP were developed. File 3 contains the consumables quantities and parameters required for crew training, flight control, launch processing, and initialization of the onboard computers.

This effort included the definition of those parameters to be stored in the Flight Data File 3 for each consumable subsystem considered, such as Electrical Power Subsystem (EPS), Environmental Control and Life Support Subsystem (ECLSS), Orbital Maneuvering Subsystem (OMS), Reaction Control Subsystem (RCS), Hydraulics, and Auxiliary Power Unit (APU). Computational methods required to convert and store the parameters of the above consumables subsystems (with the exception of the EPS Cryogenics) were formulated and documented in Reference 7.

Operations Transition Study

A study to establish refinements to the consumables management mission planning process in the transition from the development to the operational era of the STS was performed and documented in Reference 8. The refinements address methods to minimize support effort on the basic delivery system (Orbiter) based on increased confidence gained during the development era, and shift the effort to Payload support during the operational era.

Simplified Space Station MPP Task

Consumables management techniques developed under this RTOP were used to formulate a consumables model for the Space Station. This effort served the twofold purpose of: a) testing the applicability of techniques developed earlier for the STS, to advanced Spacecraft Systems, and b) establishing the basis from where tools can evolve to support the Space Station Consumables management.

The MPP was modified to incorporate the Space Station data base and revise the activity displays and input controls to reflect the Space Station activity menu. The data base workbook for the Space Station model is documented in Reference 9. The operation of the Space Station program differs from the STS program only in the activity menu from which the user selects the timeline elements.

Consumables Redline Guidelines

Guidelines for the development of consumables subsystem redlines for advanced spacecraft systems were established and documented in Reference 10.

Implementation of the MPP in conjunction with a Redline Status Subprocessor is recommended as part of the Launch Processing System (LPS).

Worksheet Update Task

The Consumables Long Range Flight Planning Worksheet is a tool developed earlier under this RTOP (Reference 11) for screening of flights to determine which flights require detailed consumables analysis. The worksheet was updated in Reference 12 to reflect current available data along with minor modifications to its format. In addition, a study establishing the accuracy of the worksheet was conducted and documented (Reference 13).

3.0 RECOMMENDATIONS/SUGGESTIONS

A Consumables Management System for reusable spacecraft and highly repetitive flights from the long-range planning stage through flight operations and spacecraft turnaround have been developed under this RTOP. The nucleus of the system, the Mission Planning Processor, and the Flight Data Files for the first 27 operational flights for the STS have been developed under Part IV of the RTOP. This latter development not only represents a test bed for the Consumables Management System, but also provides a baseline for management of operational STS Flights. It is strongly recommended that the system be used in the pending operational era flight planning and design to support an orderly transition from the current flight test development procedures to the real world of management of high frequency repetitive flights. The numerous reports issued in the course of this RTOP are not so encompassing that they can be placed on the shelf and retrieved four or five years from now to support the STS operational era. The recommendation, again, is that only continuously working with, refining, and adapting such a system will lead to the most efficient and effective consumables management in the operational era.

Several suggestions follow which are aimed at supporting the refining and adapting process in the above recommendation:

1. A multiple data base file should be set up from which the user may select individual data bases. These individual data bases would represent specific spacecraft characteristics and/or proposed spacecraft modification that will be in effect for that flight. (It should be noted that the file/retrieval system is such that, upon retrieval, the consumables data is constructed on the resident characteristic data base and is independent of the data base that was in effect when the flight data file was created.)

2. A subprocessor should be created which will generate the Long Range Flight Planning Worksheet factors from an MPP data base. This would simplify data control since both the worksheet and MPP share common data.

3. The MPP should be extended to support mass properties data generation in greater detail. Mass can be treated similar to any other consumable. Manipulator operations activity scheduling could be used to deploy and retrieve mass in conjunction with the mass depletion resulting from use of consumables. Water dump should be added as a schedulable activity to complete this mass property system.

ACRONYMS AND ABBREVIATIONS

APU	Auxiliary Power Unit
CRT	Cathode Ray Tube
DOD	Department of Defense
ECLSS	Environmental Control and Life Support Subsystem
EPS	Electrical Power Subsystem
GSE	Ground Support Equipment
JSC	Johnson Space Center
LPS	Launch Processing System
MPAD	Mission Planning and Analysis Division
MPP	Mission Planning Processor
NASA	National Aeronautics and Space Administration
OFT	Orbital Flight Test
OMS	Orbital Maneuvering Subsystem
RCS	Reaction Control Subsystem
RTOP	Research and Technology Objectives and Plans
STS	Space Transportation System